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DETECTION OF OUTGASSING IN ELECTROPLATED TIN DEPOSITS

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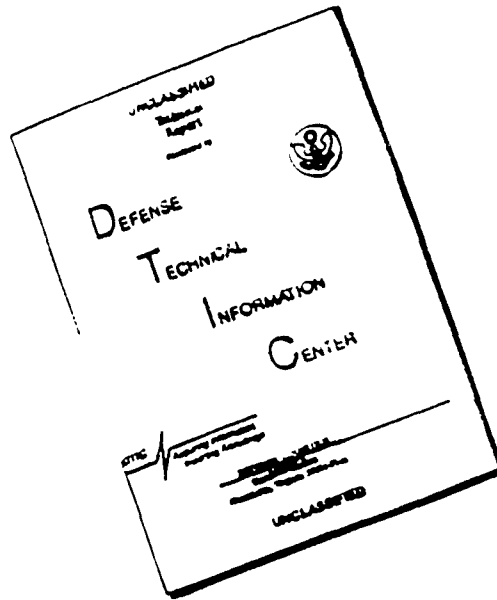
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PREFACE

1. On 15 June 1971, a matte tin finish plating bath, U. S. Patent No. 3,585,114, "Tin Plating Having Organic Compound", was issued to Dr. Henry K. Wren and William T. Hobson, assignors to the United States of America as represented by the Secretary of the Navy. This bath was designed to plate a matte tin deposit possessing very good solderability characteristics. The organic constituents of the plating bath are amenable to analytical determination and thus, predictable tin deposits can be more consistently obtained. As compared with bright acid tin deposits, the matte deposits of the so-called "Wren Tin" tin plating bath characteristically exhibit very little outgassing.
2. Because of prior solderability problems associated with bright acid tin plated finishes, MIL-M-38510E, 1 December 1981, Microcircuits, general specification for, prohibits use of bright acid tin plate as a finish for microcircuit leads, (Reference 1).
3. Those familiar with the bright acid tin plating process know how to adjust the plating parameters of a bright acid tin plating bath to produce a matte tin deposit. Such matte tin deposits are subject to the same solderability problems characteristic of bright acid tin deposits. It is evident that even if one could identify the deposits as being of bright acid tin bath origin, one could not deny that they meet the matte tin criteria of MIL-M-38510.
4. The Naval Avionics Center's Materials Laboratory thought it expedient to investigate methods for detection of outgassing in electroplated "bright acid tin deposits". The outgassing characteristics of matte deposits from generic bright acid tin baths which are operated to produce matte deposits are very similar to the outgassing characteristics of bright acid tin. Methods are proposed to differentiate between true matte tin and a matte tin finish produced by a generic bright acid tin bath.

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I. CONCLUSIONS

1. Electrolytic tin plating processes exist which yield deposits of low outgassing levels.
2. Tests have been developed which are capable of determining conformance to low outgassing electrolytic tin lead finishes.
3. At least one manufacturer can plate bright acid tin deposits that are as low in outgassing as electroplated matte or Wren tin deposits.

II. RECOMMENDATIONS

1. That the military purchase devices with "as electroplated" tin leads.
2. That acceptable limits of outgassing be determined individually for the "hot iron test", the "hot oil test", and the "mass spectrometry test".
3. That bright tin plating be neither specified nor prohibited.
4. That incoming device leads be tested by either the "hot iron test" or the "hot oil test" as agreed by both the manufacturer and the procuring activity at the beginning of the procurement process.
5. That the "mass spectrometry test" will be the "interim referee outgassing test".
6. That development of the "high vacuum melt test" be funded.

III. INTRODUCTION

The "Wren Tin" acid matte tin plating process was developed at the Naval Avionics Center in 1968 and 1969 because bright acid tin plate outgassed during soldering leaving a very porous and cratered deposit at the end of the melt zone. It was feared that this would promote electrolytic corrosion of the electronic lead material and the manner in which organics in the plated tin leads affected solderability was not known. The matte tin produced by the "Wren Tin" process adequately resolved this problem. Over the years, where long term solderability has been a prime requirement, many manufacturers have adopted the "Wren Tin" process successfully.

Even though our contacts with users of the "Wren Tin" process have been somewhat limited, we have never heard of solderability problems with this deposit and, indeed, have had users tell us how "Wren Tin", properly processed, has solved their solderability problems. Claims of excellent solderability after more than twelve months storage at room ambient temperatures have frequently been heard.

The first known published study of the solderability of Matte Tin vs. Bright Acid Tin after being subjected to elevated temperatures, was by Rance Hom, Plating Consultant to the Semiconductor Industry, (Reference 2). The results of her study showed that matte tin plating remained solderable about ten times longer than bright acid tin at the aging temperatures that were studied. MIL-M-38510E, Microcircuits, general specification for, appears to recognize the problems associated with bright acid tin as a lead finish. This specification specifically prohibits its use as a lead finish, (Reference 1).

In order to develop acceptance criteria for the specification, it is desirable to develop a test method for identifying tin electrodeposits that outgas excessively when subjected to soldering temperatures. Industry participation was recruited in supplying representative tin plated evaluation packages. The Naval Avionics Center had developed a tin outgassing test to evaluate their original work with matte tin bath development. It was decided to further refine the test and also look at other measurement techniques, (Reference 3).

Five test methods have been proposed. All have been found useful. Only the tests that can be made with readily available apparatus have been studied in depth. Each proposed test definitely has strengths and limitations. It must be noted that all of the tests studied are only applicable to unreflowed deposits.

The Naval Avionics Center generated experimental data have been summarized in Table I, Detection of Outgassing in Electroplated Tin Deposits. These data were used to optimize the "Hot Iron" and "Hot Oil" tests. These data were also used as evidence of the feasibility of developing a "High Vacuum Melt Pressure Test", a "Carbon Determination Test", and a "Mass Spectrometry Test".

Special thanks is due the participating microcircuit manufacturers for supplying the evaluation packages. This industry representative source of test devices greatly enhances the credibility of this study.

HOT IRON T

HOT IRON T											
		600±20°F			650±10°F			700±20°F			
Sample Code	Thickness (mils)	Sample	Outgass #	% Out-gassing	Sample	Outgass #	% Out-gassing	Sample	Outgass	% Out-gassing	Sample
AV	Typical = 1.0	80	2	2.5%							
BZ	K = 0.5 to 0.7	80	80	100%							
D7	R = 0.2-1.0 M552 & 591	80	61	76%							
DV	R=0.3-0.6				80	3	4%	120	16	8%	
EY		77	77	100%							
EW	0.09-0.12	77	5	6%							
CPV	Uniform 1.0 M643	80	10	13%							
CPZ		80	73	91%							
BV	R=0.12-0.18	80	0	0%							
CL17	R=0.5-0.8 M569	80	80	100%							
CL22	R=0.4-0.8 M568	24	24	100%	80	80	100%	56	56	100%	
CL37	R=0.4-0.8 M572				160	160	100%				
CL42	R=0.3-0.1 M576				160	160	100%				
CL52	R=0.5-1.5 M583				80	80	100%				80

DETECTION OF OUTGASSING IN EL

RON TEST

HOT OIL

740±30°F				740±20°F			ROOM TEMPERATURE			480±5°F			TE
Out-gassing	Sample	Outgass #	% Out-gassing	Sample	Outgass #	% Out-gassing	Sample	Outgass #	% Out-gassing	Sample	Outgass #	% Out-gassing	Sample
				80	0	0%				80	63	79%	
				80	80	100%				80	80	100%	
				80	35	44%				80	73	91%	
8%										120	74	62%	
				6	5	83%	32	32	100%	11	11	100%	
				80	0	0%							
				80	4	5%				80	64	80%	
				80	80	100%				80	80	100%	
				80	0	0%				48	26	54%	
				80	66	83%				80	80	100%	
00%										80	79	99%	
										80	80	100%	
										80	79	99%	
	80	80	100%							80	80	100%	

TABLE I

G IN ELECTROPLATED TIN DEPOSITS

HOT OIL TEST

HIGH VACUUM MELT

MASS SPECTROMETRY TEST

±5°F		TEMPERATURE AS INDICATED			PRESSURE TEST							
is #	% Out-gassing	Sample	Outgass #	% Out-gassing	Shorting Bar Side	Pressure mm Hg x 10 ⁻⁶ Initial Peak		Calculation	% Pressure Increase	Sample size milligrams	Volume of outgassing in cm	Vol Vc
	79%									10	0.23	
	100%	16 16 16	16-453±2°F 16-460±2°F 16-480±2°F	100% 100% 100%	1 2 Device 1 1 2 Device 2	2.6 2.0 2.0 2.5	8.0 6.8 6.0 7.2	8.0-2.6/2.6 6.8-2.0/2.0 6.0-2.0/2.0 7.2-2.5/2.5	208% 240% 200% 128%	10	1.6	
	91%				1 2	2.1 2.2	3.6 3.0	3.6-2.1/2.1 3.0-2.2/2.2	71% 77%	10	0.40	
	62%											
	100%											
	80%								29% 32%	10	0.34	
	100%											
	54%	48 472 16	32 + 2°F 15	67% 94%	1 2	2.1 1.9	2.7 2.5	2.7-2.1/2.1 2.5-1.9/2.5				
	100%	470 32 480	+ 2°F 32 + 2°F	100%								
	99%											
	100%											
	99%											
	100%	15 480	+ 2°F	100%	2	2.1 2.3	4.4 4.5	4.4-2.1/2.1 4.5-2.3/2.3	110% 96%			

SS SPECTROMETRY TEST			CARBON DETERMINATION			COMMENTS
Sample Size Grams	Volume of outgassing in cm	Volume outgassing Volume of tin	%	%	%	
10	0.23	0.8	0.016	0.016		
10	1.6	5.7				
10	0.40	1.4	0.030	0.030	0.053	
						Pin quite heavy on lead shoulders as received. Cutting revealed large gas voids as received.
10	0.34	1.2				
			0.016	0.016	0.016	
						Supplier suggested bath make up, 10 volume % starter, 310C, still plated at 15A/ft ² .

IV. TEST METHODS

A. "HOT IRON TEST"

1. Discussion

Circa 1968 the "Hot Iron Test" was discovered by a production line nand solderer at our facility. She reported that the bright acid tin plating on stand-off terminals boiled when touched with a soldering iron. Investigation substantiated the descriptive accuracy of her observation. A version of the Hot Iron Test has been used here on an informal basis with no written procedure since then. This portion of the current study has attempted to optimize and standardize an old procedure.

Fourteen different lots of evaluation packages from outside vendors and devices plated in NAC laboratory and production baths were represented. There were (8) lots of bright acid tin plating on Alloy 42 leads, (4) lots of matte acid tin plating on Alloy 42 leads, (1) lot of matte acid tin plating that had been furnace reflowed on Alloy 42 leads, and (1) lot of matte acid tin plating that had been hot solder dipped on Alloy 42 leads. Each lot was assigned a code number as received and the typical thickness of the lead finish was determined by metallographic sectioning.

It was originally intended that (80) leads from each lot would be tested at 600°F and that an additional (80) leads would be tested at 800°F.

About midway of the investigation, it became apparent that neither the 600°F setting nor the 800°F setting represented an optimum temperature for the test. The heat transfer was too slow at 600°F and it was too fast at the 800°F setting. Accordingly, some lots were run at 650°F, 700°F, and 750°F settings. The 650°F setting represented the best heat transfer rate for both sensitivity and convenience. The remainder of the "hot iron testing" was done at a temperature setting of 650°F, which, by calibration, was found to be actually $650 \pm 10^\circ\text{F}$. The soldering station used was not calibrated until the "Hot Iron Test" was completed. The results of the calibration are shown in Table II. A summary of all test data in this report is found in Table I, Detection of Outgassing in Electroplated Tin Deposits.

TABLE II - CALIBRATION OF SOLDERING IRON USED IN "HOT IRON TEST"

Set Temperature °F	Actual Iron Temperature Range °F
600	600°F + 20°F - 0°F
650	650°F + 10°F -10°F
700	700°F + 0°F -20°F
750	740°F + 0°F -30°F
800	740°F + 0°F -20°F

The "hot iron test" will not give false indications of outgassing. It is not the most sensitive method of detecting low levels of outgassing characteristic of true matte tin deposits. It is only valid when used on deposits which have not been reflowed. It is also possible for a careless tester to apply the hot soldering iron for too long a period and miss indications of outgassing. But, under no circumstances can a vendor be charged with outgassing that his tin plating does not exhibit. It is a safe test for the vendor. Tester training requirements are minimal and the cost of test apparatus is minimal. Like all tests, it has both strengths and weaknesses. These are listed in Table III, Evaluation of "Hot Iron Test".

TABLE III - EVALUATION OF "HOT IRON TEST"

Strengths	Weaknesses
<ol style="list-style-type: none"> 1. Nondestructive 2. Cannot indicate outgassing that does not exist 3. Rapid 4. Documentable 5. Apparatus is affordable 6. Apparatus is readily available 7. Nonhazardous 8. Lighting for microscopy is readily available 9. Has been used in principle for years 10. Formalized for use on Hull Cell Plating Panels (Reference 4) 	<ol style="list-style-type: none"> 1. Only valid for unreflowed deposits 2. Is not sensitive to low levels of outgassing 3. Skill dependent (requires operator training) 4. Inspection is by attributes (does or does not outgas); amount of outgassing not reliably quantifiable 5. Sensitivity of test is dependent upon microscopy light source 6. Excessive knife pressure normal to the axis of the lead wire can mask gas porosity by mashing gas voids shut 7. Would be very difficult to automate

2. Recommended Procedure Hot Iron Test

Select a calibratable soldering iron equipped with a 2-1/8" wide chisel bit. Adjust the temperature to $650 \pm 10^\circ\text{F}$.

Mount the device to be tested in a drill vise or similar fixture suitable for viewing with a stereozoom microscope at 20 to 30 power.

At 20X, select the area of the tin plated lead to be tested.

Wipe the soldering iron bit on a moistened sponge until it is dry (dry in the sense that the bit is bright, but so starved for solder that very little if any solder will deposit on the lead wire being tested).

Touch the bit to the selected area of the tin plated lead wire to be tested. Hold it there until the crest of the melted tin wave front appears to be appreciably higher than the unmelted tin plated lead surface. (This will normally occur at $1/8 \pm 1/16$ inches from the point of heat application).

Remove the iron quickly.

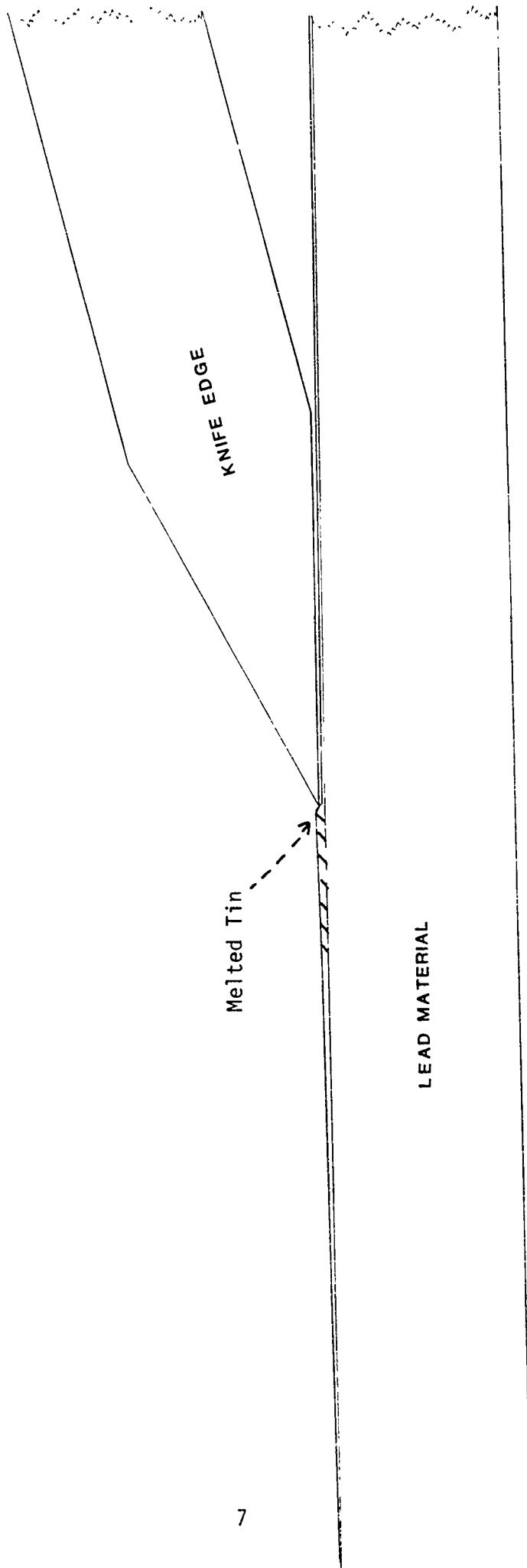
Allow the melted tin to cool.

With a very sharp knife or scalpel, slice the wave face at about one-half the distance between the crest of the wave of tin that has been melted and the surface of the unmelted tin. Cut toward the point of heat application. Direct the knife so that there is minimal pressure normal to the axis of the lead, i.e., apply cutting pressure parallel to the axis of the lead wire. Terminate the slice at the surface of the melted tin at least 1/32 inch away from the nearest point of heat application.

Adjust the microscope to 30X and examine the cut surface for gas porosity (sections of spherical voids).

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"401 IRON TEST" KNIFE CUTTING METHOD



If no voids are found, it is permissible to take another cut with the scalpel or knife.

If voids are found, they can be documented by color photography, or the tested leads can be retained. (Careful handling and storage procedures should be utilized).

A testing operator should adjust to the test at the beginning of a test period, when either a new lot is introduced or a different lead wire geometry is introduced. It is preferable to run a minimum of three leads for this adjustment and these leads shall not be considered as part of the statistical sample. (See Appendix A, page A-1, Apparatus Used in Development of "Hot Iron Test").

B. "HOT OIL TEST"

1. Discussion

The "hot oil test" is a variant of the "hot knife test". Heat is used to melt the electrodeposited tin lead finish and the resultant melted tin is examined for gas porosity. This method was not seriously considered initially as a part of this test development program because it was felt it had so little to contribute that was different. It was apparent very quickly that the "hot oil test" is much more sensitive to low amounts of outgassing than the "hot iron test". The heat sinking effect of the device enables one to stop the melting of the tin before all of the tin on the leads has melted. This, together with the combined effect of the hydraulic pressure of the oil and its wetting characteristics, allows the gases that are being released by the heat effect to grow larger bubbles than when the tin is melted in air as in the "hot iron test". In this study, peanut oil was used because of its availability in the laboratory. Most any tin fusing oil would give similar sensitivity.

Accordingly, the decision was made to spend the remainder of our evaluation packages on the "hot oil test" at $460 \pm 5^\circ\text{F}$. In optimizing the "hot iron test", 2280 leads were tested at various temperatures with 1317 leads found to have outgassing tin deposits, i.e., 58% of leads tested were found outgassing. In the "hot oil test", 1139 tin plated leads were tested at various temperatures with 973 leads found to have outgassing tin deposits, i.e., 85% of leads tested were found to have outgassing tin deposits.

If one looks at the matte tin deposit only, 680 tin plated leads were tested by the "hot iron test" with 35 leads found to have an outgassing tin deposit, i.e., 5% of leads tested were found to have outgassing tin deposits. With the "hot oil test", 344 tin plated leads were tested in peanut oil at $460 \pm 5^\circ\text{F}$ with 188 leads found to have an outgassing tin deposit, i.e., 55% of the leads tested were found to have an outgassing tin deposit.

One lot of evaluation packages tested by the "hot iron test" showed zero leads outgassing out of 160 leads. Ninety-six leads from the same lot of evaluation packages, tested by the "hot oil test", showed 58 leads to have outgassing tin deposits, i.e., 60% of the leads tested were found to have an outgassing tin deposit.

Obviously, if the "hot oil test" is used to test tin plated leads for outgassing tin deposits, it now becomes necessary to define how much outgassing is acceptable. This question is not answered with the data we have generated thus far. This, and the other tests which are detailed as preliminary feasibility studies only, conclusively, shows that, as expected, a really sensitive test method will show that all acceptable engineering electroplated acid sulfate tin deposits will outgas when melted. Since all commercially acceptable sulfate acid tin plating baths employ an organic addition agent or agents, it is realistic to assume that some of the addition agent, or its degradation compounds, will either be codeposited or mechanically occluded during the plating process.

Ideally, there should be no organics in the electroplated tin deposit used as a finish on an electronic lead intended to be joined by tin-lead soldering. In the "real world", using acid sulfate tin plating baths, -- both bright acid tin baths and matte acid tin baths are acid sulfate tin plating baths which differ primarily in the choice of plating addition agents employed -- it is not likely that tin will ever be electrodeposited that does not contain some organic components.

The "hot oil test" should not present an unmanageable fire hazard. Peanut oil, with a characteristic flash point of 550°F, should present only a small fire hazard if good thermal management is considered in the design of the test apparatus.

The "hot oil test" does not give false indications of outgassing. It is a much more sensitive test for low levels of outgassing, characteristic of true matte tin deposits, than the "hot iron test". It is only valid when used on deposits which have not been reflowed (deposits in the "as plated" condition). It is also possible for a careless operator to use too long a dwell in the hot oil and miss indications of outgassing. But, under no circumstances, can a vendor be charged with outgassing that his electrodeposited tin plating does not exhibit. It is a safe test for the vendor. Tester training requirements are minimal and the cost of test apparatus is minimal.

TABLE IV - EVALUATION OF "HOT OIL TEST"

Strengths	Weaknesses
<ol style="list-style-type: none"> 1. It may be non-destructive 2. Sensitive to low levels outgassing 3. Can not detect outgassing that does not exist 4. Very rapid 5. Documentable 6. Apparatus is affordable 7. Apparatus is readily available 8. Lighting for microscopy is readily available 9. Hot oil portion is amenable to automation 	<ol style="list-style-type: none"> 1. <u>Only valid for unreflowed deposits</u> 2. <u>Skill dependent (requires operator training)</u> 3. Inspection is by attributes (does or does not outgas); amount of outgassing not reliably quantifiable 4. Sensitivity of test is dependent upon microscopy light source 5. Excessive knife pressure normal to axis of the lead wire can mask gas porosity by mashing gas voids shut 6. Some operator burn and fire hazard

2. Recommended Procedure Hot Oil Test

(1) Heat peanut oil in a stainless steel container to $465 \pm 5^\circ\text{F}$ and maintain at $465 \pm 5^\circ\text{F}$. Caution: To lower the risk of burns and fire the peanut oil shall not be heated in a glass container.

(2) Attach the tin plated wire lead devices to be tested for outgassing to a suitable hanger.

(3) Enter hot peanut oil at a velocity of $1 \pm 1/4$ inch/sec.

(4) Dwell in hot peanut oil for $5 \pm 1/2$ sec.

(5) Exit hot peanut oil at a velocity of $1 \pm 1/4$ inch/sec.

(6) Allow to cool and examine for extent of reflow. The dwell time is optimum when about $2/3$ of the tin plated lead surface has melted.

(7) If the above criterion is not met, adjust dwell time until the criterion of Step 6 above is met.

(8) Mount the device in a drill vise or similar fixture suitable for viewing with a stereozoom microscope at 20 to 30 power.

(9) Adjust the magnification to 20 power.

(10) With a very sharp knife or scalpel, slice the wave face about one-half the distance between the crest of the wave of tin that has been melted and the surface of the unmelted tin. Cut toward the propagation of the melt zone. Direct the knife so that there is minimal pressure normal to the axis of the lead, i.e., apply cutting pressure parallel to the axis of the lead. See Figure 1.

(11) Adjust the microscope to 30X and examine the cut surface for gas porosity (sections of spherical voids).

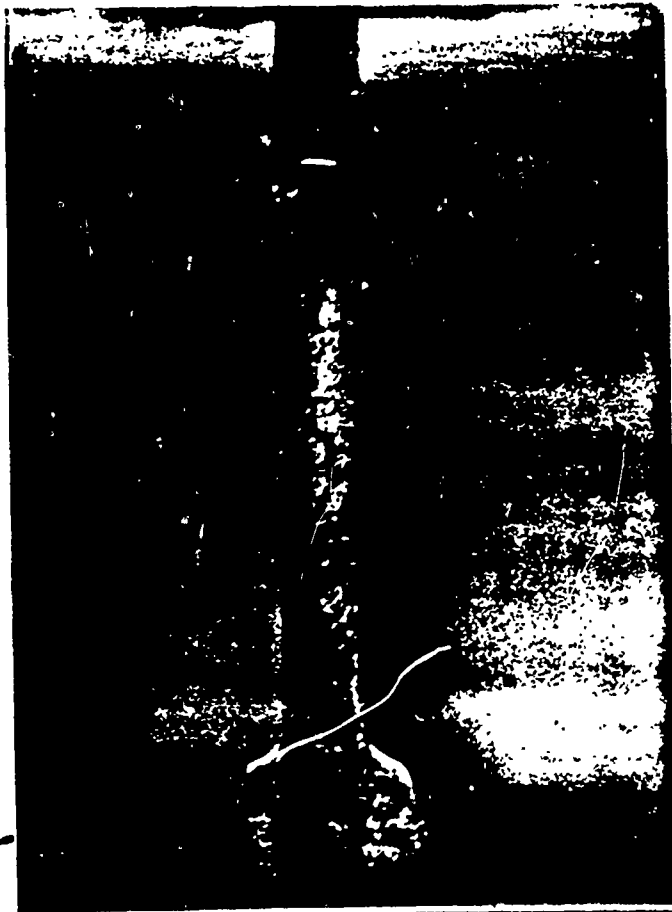
(12) If no voids are found, it is permissible to take another cut with the scalpel or knife.

(13) If voids are found, they can be documented by color photography, or the test pieces can be used as exhibits. (Careful handling and storage procedures should be utilized.)

(14) A testing operator should adjust to the test at the beginning of a test period, when either a new lot is introduced or a different lead geometry is introduced. It is preferable to run a minimum of (3) leads for this adjustment and they shall not be considered as a part of the statistical sample. (See Appendix B, page B-1, Apparatus Used in Development of "Hot Oil Test").

3. Photo Documentation

Both the "hot iron test" and the "hot oil test" which are evaluated in a stable condition, are amenable to photo documentation. The following photos are included to illustrate this technique. Photo No. 1 is of the least outgassing sample of electroplated matte tin lead-finish that NAC evaluated. The evaluation was by the "hot oil test". At approximately (20) power (2) gas pits are identifiable in the sliced zone. The "hot iron test" on this same lot did not show any documentable (by photography at approximately (20) power)) gas pits. Photographs of this are not included. Photo No. 2 is of a bright acid tin plated lead that was examined by the "hot iron test". Numerous gas pits are visible at approximately (20) power. Photo No. 3 is a lead from the same lot of cer-dips that was examined by the "hot oil test". It is evident that the slicing of the melt zone merely confirms visual evidence of much outgassing.



Photograph No. 1
Matte Acid Tin - "Hot Oil Test"



Photograph No. 2
Bright Acid Tin - "Hot Iron Test"



Photograph No. 3
Bright Acid Tin - "Hot Oil Test"

C. "HIGH VACUUM MELT PRESSURE TEST"

1. Discussion

The high vacuum melt pressure test data can be used to directly calculate the volume of gas that has been evolved. Of all the tests we have investigated, it is the one that can most directly measure the volume of gas that has been released when the tin plating has been melted on the tin plated lead.

Even though the size of our "High Vacuum Melt Pressure Test" apparatus could be likened to using an elephant trap to trap a mouse, the results we obtained were in the same order as that obtained using the "hot iron test". Our data were obtained from a dynamic rather than a static system. However, it can be shown that the results obtained in a dynamic steady state system are proportional to results obtained in a static system. The Naval Avionics Center has not researched vacuum apparatus, but we feel confident that standard components are available which would be amenable to scaling down the system and operating the melt cycle as a static system. The Naval Avionics Center envisions an optimized "high vacuum melt pressure test" as becoming the referee test for outgassing of electroplated tin deposits.

The "high vacuum melt pressure test" should have good sensitivity over the entire range of outgassing that would be experienced with commercial acid sulfate tin deposits. Like all of the tests this study encompasses, it is only applicable to electroplated tin deposits that have not been melted (reflowed). Barring a sudden and coincidental increase in leak rate, there is no other way that the "high vacuum melt pressure test" would indicate outgassing that did not exist, providing that the test specimen has been adequately cleaned. Since this is unlikely and should be noticed by an experienced tester, this test method should be a test that would not indicate false outgassing of tin deposits.

The "high vacuum melt pressure test", in our opinion, could be automated to the point that an operator would only have to clean and weigh the sample and introduce it into the high vacuum chamber. In a very short time, a hard copy of the amount of outgassing is in hand. Not magic -- just application of current microprocessor technology. The test results would be by measurement, not by attributes, and would be much more amenable to process control and statistical evaluation. Like all tests it has both strengths and weaknesses. These are listed in Table V, Evaluation of "High Vacuum Melt Pressure Test".

TABLE V - EVALUATION OF "HIGH VACUUM MELT PRESSURE TEST"

Strengths	Weaknesses
<ol style="list-style-type: none"> 1. Sensitive to full range of outgassing amounts 2. Properly used, cannot indicate outgassing that does not exist 3. Rapid 4. Test appears very amenable to automation; it could be designed to give a hard copy printout of the amount of outgassing found 5. <u>Test measures the amount of gas released by the melted tin plate, not just evidence that outgassing took place</u> 6. <u>Test is as near operator independent as a test can be</u> 	<ol style="list-style-type: none"> 1. <u>Only valid for unreflowed deposits.</u> 2. It is a destructive test, but it is possible that lead "clippings" would provide a sufficient sample 3. High vacuum equipment is rather expensive 4. Every laboratory does not have the available apparatus 5. Sample must be free of surface soil and then handled so that it remains clean

2. Feasibility Test Procedure of High Vacuum Melt Test

- (1) Remove the tin plated lead wire from the device.
- (2) Clean the tin plated lead wire as follows:
 - a. Pick up the tin plated lead wire with a hemostat.
 - b. Slosh the tinplated lead wire in room temperature glass distilled methylene chloride contained in a suitable glass beaker.
 - c. Vapor degrease in glass distilled methylene chloride until condensation nearly ceases.
 - d. Repeat Step "b".
 - e. Repeat Step "c".
- (3) Remove the bell jar from the test area it isolates.
- (4) Without touching with fingers, attach the ends of tin plated lead to be tested for outgassing so that it is in series with variable electrical power source.
- (5) Check electrical continuity of the set-up.
- (6) Place the bell jar over the test area.

(7) Pump the bell jar with the mechanical vacuum pump until the pressure is less than 1×10^{-5} mm of Hg (Torr).

(8) Switch to the vacuum diffusion pump and pump until the electronic tube vacuum gage reads 2.5×10^{-6} mm of Hg (Torr) or less. With the pump running, have one person close the electrical resistance heating circuit (the tin plated alloy 42 lead is the resistance) until the tin plated lead wire just glows and open the electrical circuit at that moment. At the same time, an observer is watching the electronic vacuum gage and notes the high point of the transient pressure spike.

(9) The percentage increase in pressure is calculated as follows:

$$\frac{\text{Instantaneous Peak Pressure} - \text{Steady State Pressure}}{\text{Steady State Pressure}} \times 100\% = \text{Percentage increase in pressure}$$

(See Appendix C, page C-1, Apparatus Used in Feasibility Study of "High Vacuum Melt Test").

D. "MASS SPECTROMETRY TEST"

1. Discussion

Having established that all deposits the Naval Avionics Center has tested from acid sulfate tin baths do, indeed, outgas -- the amount of outgassing should be a basis of acceptability. Mass spectrometry should, at least, reveal the composition of released gas. Four lots were selected for investigation by mass spectrometry. The two extremes of outgassing from bright acid tin plated evaluation package lots were submitted to a laboratory for analysis. Also, the two extremes of outgassing from matte tin plated evaluation package lots were also sent to the same laboratory for analysis of all the gas collected from a sample tin plated alloy 42 lead that had been subjected to 650°F for five minutes.

The results in micrograms per gram of sample (either bright or matte tin plated alloy 42 leads) appear in Table VI, Mass Spectrometry Analysis. The total volatiles reported were summed and this indicated that the total weight amounts of volatiles detected are in the same order that the lots had been ranked by the "hot iron test".

A computer program was written to convert the microgram/gram amounts into volumes of gas at standard temperature and pressure (STP) expressed as cm³/gram. These values more nearly coincide with the actual volume of gas that had offgassed (outgassed).

The volume of tin that was plated on a one gram sample of tin plated alloy 42 lead was computed. Some approximations were made in measuring. This volume of tin was used to compute the volume outgassing/volume of tin plating in Table VII. See page F-1 in Appendix for computation.

TABLE VI - MASS SPECTROMETRY ANALYSIS

COMPOUND	SAMPLES			
	AV	BZ	CV	DZ
	<u>Micrograms/gram</u>			
Hydrogen	0.223	0.154	0.454	0.464
Methane	0.123	0.479	0.765	0.728
Water	13.500	85.400	14.500	13.600
Ethylene	1.270	22.300	3.320	8.400
Nitrogen	0.000	0.000	0.000	0.000
Ethane	0.417	8.230	1.950	1.740
Ethanol	0.000	11.300	1.319	2.990
Oxygen	0.021	0.585	0.049	0.083
Argon	0.137	0.447	0.314	0.311
Unsaturated hydrocarbons as butene	0.748	3.760	1.120	1.210
Saturated hydrocarbons as butane	0.529	1.070	2.180	2.560
Carbon dioxide	3.520	8.540	7.180	4.500
Isopropyl alcohol	0.000	6.830	0.000	0.530
Unidentified compound m/e 74	0.000	23.600	0.442	2.850
Benzene	0.000	0.000	0.416	0.000
Unidentified compound m/e 117 possibly O-Allyltoluene	<u>0.000</u>	<u>28.200</u>	<u>0.000</u>	<u>12.300</u>
TOTALS	20.5	201	33.9	52.3

TABLE VII - MASS SPECTROMETRY ANALYSIS OF TABLE VI
EXPRESSED AS VOLUMES OF GAS AT STANDARD TEMPERATURE AND PRESSURE

COMPOUND	CODE	M/E	AV	BZ	CV	DZ
Centimeters ³ /gram						
Hydrogen		2.0158	.0024780	.0017113	.0050449	.0051561
Methane		16.0400	.0001718	.0006689	.0010683	.0010167
Water		18.0153	.0167857	.1061853	.0180291	.0169101
Ethylene		28.0500	.0010142	.0178082	.0026513	.0067080
Nitrogen		28.0134	.0000000	.0000000	.0000000	.0000000
Ethane		30.0700	.0003106	.0061308	.0014526	.0012962
Ethanol		46.0700	.0000000	.0054942	.0006413	.0014538
Oxygen		31.9988	.0000147	.0004095	.0000343	.0000581
Argon		39.4800	.0000777	.0002536	.0001782	.0001765
Butene		56.1200	.0002986	.0015008	.0004470	.0004830
Butane		58.1300	.0002038	.0004123	.0008400	.0009865
Carbon Dioxide		44.0100	.0017916	.0043466	.0020544	.0022904
Isopropanol		60.1100	.0000000	.0025452	.0000000	.0001975
M/E 74		74.0000	.0000000	.0071438	.0001338	.0008627
Benzene		78.1200	.0000000	.0000000	.0001193	.0000000
ME/117		<u>117.0000</u>	<u>.0000000</u>	<u>.0053990</u>	<u>.0000000</u>	<u>.0023549</u>
Total Volume, STP			.0231467	.1600095	.0342945	.0399505
Total Volume, Significant			0.0232	.160	0.0343	0.0400
*Volume Outgassing/Volume of Tin Plating			.8	5.7	1.2	1.4

*As several approximations have been made, this should be considered a figure of merit for comparison purposes. See page F-1 in Appendix for computation.

The sample that consistently had the least outgassing by all test methods investigated, produced a gas volume (0.8) times the volume of tin plating that was deposited. The sample that consistently had the most outgassing by all test methods investigated, outgassed 5.7 times the volume of tin plating that was deposited. No temperature correction was computed but, in actuality, the volume of outgassing at 650°F would be on the order of two times as much as the amount computed for standard conditions.

The "mass spectrometry test" was a limited feasibility study. Mass spectrometry analysis can be obtained, but it is quite expensive. At this stage, it appears to be a good tool to use in researching plating processes and, perhaps, is a suitable interim referee test for compliance to an outgassing limitation in a specification. The mass spectrometry test has both strengths and weaknesses. The more apparent ones are listed in Table VIII, Evaluation of "Mass Spectrometry Test".

TABLE VIII - EVALUATION OF "MASS SPECTROMETRY TEST"

Strengths	Weaknesses
<ol style="list-style-type: none"> 1. Sensitive to full range of outgassing amounts 2. Properly used, cannot detect outgassing that does not exist 3. Rapid 4. Mass spectrometry is an accepted analytical method 5. <u>Test measures the amount of gas released by the melted tin plate</u> 	<ol style="list-style-type: none"> 1. <u>Only valid for unreflowed deposits</u> 2. It is a destructive test but it is possible that lead "clippings" would provide a sufficient sample 3. Analytical Mass Spectrometers are expensive 4. Every laboratory does not have the available apparatus 5. Sample must be free of surface soil and then handled so that it remains clean

2. Feasibility Test Procedure of Mass Spectrometry Test

This test was accomplished by an outside contractor for the Naval Avionics Center. The following is the contractor's reported method:

(1) Tin plated leads to be tested for outgassing were cleaned in the following manner and never again touched by human fingers:

- a. Dipped one minute in room temperature glass distilled methylene chloride.
- b. Degreased one minute in glass distilled methylene chloride vapor.
- c. Dipped one minute in room temperature glass distilled methylene chloride.
- d. Degreased one minute in glass distilled methylene chloride vapor.

(2) A 10 mg sample from the shorting bar of a 14/16 lead cer-dip was introduced into a mass spectrometer. The piece measured approximately 0.17" long x 0.04" wide x 0.010" thick, plated, except for the cut ends, with 0.001" Sn. A blank was run just prior to the sample. The vacuum chamber in which the sample had been placed was evacuated to 10^{-6} Torr (10^{-6} mm. of Hg). The sample was then heated to 650°F for five minutes and all offgassing (outgassing) was collected and analyzed. The results are reported in Table VI, Mass Spectrometry Analysis, page 15. (See Appendix D, page D-1, Apparatus Used in "Mass Spectrometry Test").

F. "CARBON DETERMINATION TEST"

1. Discussion

It has long been known that the carbon content of most metals can easily and reliably be determined by pyrolysis of the metal in an excess of oxygen in an isolatable system. The carbon content of the metal is calculated from the amount of evolved carbon dioxide. There is no reason why this cannot be applied to electroplated tin deposits. Hom, Reference (2), reported that the carbon content of matte tin was appreciably lower than the carbon content of bright tin. No claim was made that these carbon contents were to be considered as typical. However, our results are in reasonable agreement. See Table IX.

TABLE IX - COMPARISON OF CARBON CONTENT OF ELECTROPLATED TIN

Matte Tin % Carbon			Bright Tin % Carbon			
Hom #1	Hom #2	NAC-BV	Hom #1	Hom #2	NAC-BZ	NAC-DZ
0.032	0.039	0.016	0.16	0.17	0.12	0.041

The Naval Avionics Center determined the carbon content of the electroplated tin finish on alloy 42 leads directly (by pyrolytic action on the alloy 42 leads which had been electroplated with tin). The amount of tin was estimated as the difference in weight of a plated lead and a lead of the same dimensions which had not been electroplated (a bare alloy 42 lead). Our results should not be as accurate as the Hom results which were obtained on electroplated tin deposits only, i.e., electroforms of tin. It is, however, known that all of the carbon reported was due to the electroplated tin, for a carbon determination on bare alloy 42 lead material showed no detectable carbon.

It was planned to get a step closer to reality by weighing, chemically stripping, and reweighing the stripped equivalent tin plated alloy 42 leads to determine the amount of tin that constituted the sample. Two proprietary tin-lead strippers used to strip tin-lead plating from copper conductors on printed wiring boards were available at NAC -- but were not successful. One stripper would not strip tin in a reasonable length of time. The other stripped the tin promptly and proceeded to attack the alloy 42. The tin stripping approach is sound. Chemical tin strippers that should strip tin and stop dead at the alloy 42 are known (at least in principle). With just a little more apparatus, it is well known that hot caustic will electrolytically strip tin with no attack on a ferrous substrate (alloy 42 is 42 wt. % nickel - balance iron with some minor impurities).

Since this is only a feasibility study, the carbon content method was not perfected. It is assumed that the carbon found was from the electroplated tin and that each sample had approximately the same weight of electroplated tin finish. Our found percentage of carbon is approximate, but well within the ball park.

2. Feasibility Test Procedure of Carbon Determination Test

(1) Samples of cer-dip tin plated alloy 42 leads were subjected to the pyrolytic action of a high frequency induction furnace. The resultant carbon dioxide concentration was measured as carbon with a carbon determinator using matched thermistors to measure the thermal conductivity of the $O_2 - CO_2$ gas mixture. Samples of 1.3 to 1.5 grams were weighed on an analytical balance to 0.1 mg. accuracy. These samples were then transferred to ceramic cupelets and ignited in the high frequency induction furnace. The analyzer had been calibrated using standard steel samples of known carbon concentrations.

(2) The sample size of electroplated tin was determined by difference from a similar sample of bare alloy 42.

(3) Bare alloy 42 revealed no carbon content when analyzed as above. Therefore, it was assumed that any carbon dioxide evolved and measured, resulted from organic inclusions in the electroplated tin deposit. (See Appendix E, page E-1, Apparatus Used in Feasibility Study of "Carbon Determination Test").

V. SUMMARY DISCUSSION

As the evaluation packages, submitted by semiconductor firms, proceeded through the various test studies, two things became evident -- (1) it must be considered that all commercial acid sulfate tin baths can produce deposits which outgas. (2) at least one manufacturer can plate bright acid tin deposits that are considered to be as low in outgassing, as electroplated true matte tin deposits.

All of the methods investigated could be developed into useful test procedures for detecting outgassing in electroplated tin deposits. They all have unique strong points and unique weaknesses. They all share one common limitation -- they are only applicable to electroplated tin deposits which have not been melted (reflowed). Deposits which have excessive outgassing characteristics leave telltale signs in the reflowed deposits. These signs are so subtle that it is unlikely that routine inspection could ever be efficiently accomplished by such metallographic test procedures.

The "hot iron test", employing a controllable temperature soldering iron at 650°F, is an optimization of an informal test procedure that has been around for at least 14 years. It is sensitive enough to detect outgassing in the lowest outgassing bright acid tin that was tested by that method. It is a skill dependent test and somewhat subjective. It is amenable to documentation by color photography or by careful storage of the leads that have had their

electroplated tin lead finish melted by the "hot iron" and confirmed by observation of gas pits when "sliced" per the "hot iron test" procedure. It is not a test which yields easily quantifiable results. It is an inspection by attributes test.

Hot melt solderability tests have been used for years. A good example is the solderability "dicky bird test" (MIL-STD-883B, Method 2003.2) -- an attributes test (it either covers with solder or it leaves voids - uncovered areas). The solderability test has been quantified by a percentage coverage requirement. A similar statement of inspection could be: "Leads which exhibit three or more voids visible at 30 power shall be considered as having outgassed. Lot inspection by attributes shall be based on the number of leads having three or more confirmable (documentable) gas pits. Leads with less than three gas pits shall be considered as not outgassing".

The "hot oil test" is more sensitive than the "hot iron test" to low levels of outgassing. Like the "hot iron test", it will not lie and find outgassing that does not exist. The outgassing cycle of the test is less operator sensitive than the "hot iron test" and could be easily automated for enhanced repeatability. The slicing of the meltzone and interpretation of results is still dependent on a skilled tester. Inspection by attributes is most applicable. Documentation can be by photography or retention of test specimens.

The "high vacuum melt test", based on feasibility test results, promises to consistently measure the volume of gas released by melting an electroplated tin lead wire finish. This test more directly measures the volume of gas outgassing than any of the other tests explored. Statistical evaluation of test results could reliably be performed. The Naval Avionics Center test utilized oversized equipment which was available. See Appendix page C-1. It appears to be a test which could be designed to be completely automatic and deliver results as "hard copy". This test could well be refined and become the industry referee outgassing test.

The mass spectrometry test gives more information than any other test method investigated. Within limits, it can measure the volume of specific molecules which have offgassed from an electroplated tin finish on a lead wire. Interpretation as to the exact compounds in the tin plated deposit, which either outgassed directly or, under the influence of heat, reacted to produce the measured molecular constituents, would be difficult and somewhat controversial. Every shop can't afford a mass spectrometer, but it represents an approach that utilizes an accepted analytical technique. At present, it is probably most applicable for research and development of acid sulfate tin plating processes.

The "carbon determination test" is an old, reliable, analytical method which is most used for the determination of the carbon content of ferrous alloys. Apparatus is available which gives rapid, accurate analyses of carbon in steel, cast iron, and other ferrous alloys. There is no reason to expect that it would be less accurate in determining the carbon content of electroplated tin deposits.

The three sample lots which were evaluated for carbon content were found to have different carbon contents. When ranked according to the carbon content, they conformed to the ranking of the other four tests. While gratifying, this is not necessarily conclusive. At present, the "carbon determination test" is thought to be more applicable for predicting the amount of black, carbonaceous material that may be found in an electrolytic tin deposit after exposure to long periods of elevated temperature, such as "burn in".

The most mature method of testing for outgassing of electrolytic tin finishes on electronic leads is the "hot iron test". It has been informally used for at least 14 years. It is not sensitive to low levels of outgassing characteristic of matte tin deposits of the "Wren Tin" family of acid sulfate tin plating processes. It is sensitive enough for most any operator to find "grossly" outgassing electrolytic tin deposits. Apparatus used for the test is available in most microcircuit device user's laboratories. With minimal operator training, this test can be employed to inspect incoming tin plated leads on a go no-go basis.

The "hot oil test" has been developed so that it can detect low levels of outgassing characteristic of matte tin deposits of the "Wren Tin" family of acid sulfate tin plating processes. The "state-of-the-art" of acid sulfate tin plating processes dictates that, if this test is used, some amount of detectable outgassing must be acceptable. The microcircuit industry and the Department of Defense can cooperatively set this limit. Neither the "hot oil test" nor the "hot iron test" can report outgassing deposits which do not exist. They are safe tests for the manufacturer.

The "high vacuum melt test", the "mass spectrometry test", and the "carbon determination test" have only been tested for feasibility of development. The prospects for the development of all three test methods are encouraging. They are second generation tests and, in the cases of the "high vacuum melt test" and the "mass spectrometry test", give a directly calculable measure of the amount of outgassing that a unit volume of tin plating outgasses. The "carbon determination test" gives quantitative numbers which should usually, but not necessarily, be directly substantiative of the expected amount of outgassing.

Acceptance limits have not been set for any of the test methods studied. Since each test has a different characteristic sensitivity for detecting outgassing of electroplated tin lead wire finishes, it is necessary that each test shall have a unique acceptance limit. Test reproducibility is such that realistic acceptance limits can be set for each test.

A Hull Cell outgassing test, formally described some nine years ago, Reference (4), routinely run in addition to the chemical and physical tests normally used for bath control, can enable the manufacturer to know his process is such that unacceptable levels of outgassing will not be found in his tin plated device leads. This test was the test used in developing the "Wren Tin" acid sulfate tin plating process, which has long been known for tin deposits which exhibit low outgassing and outstanding long term solderability.

The most eloquent statement of the validity of this investigation is Table X - Correlation of Test Results. The ranking of the amount of outgassing found in the device leads from various sources is in the same order by each test method.

TABLE X - CORRELATION OF TEST RESULTS

CODE	"Hot Iron Test"	"Hot Oil Test"	"High Vacuum Melt Test"	Mass Spectrometry 650° for 5 min.			Carbon Determination		
	% Found Outgass.	% Found Outgass.	% Pressure Increase	$\frac{\mu g}{g}$	$\frac{cm^3}{g}$	$\frac{Vol. Outgass.}{Vol. of Tin}$	Sample		
							1	2	3
							%	%	%
BV	0	54	29 32	-	-	-	0.016	0.016	-
AV	2.5	79	-	20.5	0.23	.8			
CPV	13	80	-	34.0	0.34	1.2			
DZ	76	91	71	52.3	0.40	1.4	0.030	0.039	0.053
BZ	100	100	208 240	201	1.60	5.7	0.123	0.124	

APPENDIX A

Apparatus Used in Development of "Hot Iron Test"

Apparatus	Comments
1. Stereozoom microscope, 7 to 30 Power	1. Bausch & Lomb or equivalent
2. Two parallel penlight fluorescent tubes mounted on either side of the objective lens were used to provide flatfield illumination. (No longer available from AO Spencer)	2. Use either: (a) Bausch & Lomb Ring Illuminator with Power Supply (b) American Optical 384 Ring Illuminator with Power Supply
3. A controllable temperature soldering iron (1/8" wide chisel bit) capable of $650 \pm 10^{\circ}\text{F}$. (Hexacon)	3. Hexacon and other soldering iron manufacturers can supply
4. Drill Vise	4. Or other suitable fixture
5. Bard & Parker No. 5 Knife Handle with No. 15 Blade	5. Or other suitable knife or scalpel
6. Polaroid MP-4 Land Camera	6. Very useful where photographic documentation is employed. There are alternatives, but be sure of ability to do the job
7. Leitz Wetzlar MM6 Metallograph	7. Useful in developmental work, not required for routine testing
8. ISI Super IIIA Scanning Microscope	8. Useful in developmental work, not required for routine testing

APPENDIX B

Apparatus Used in Development of "Hot Oil Test"

Apparatus	Comments
1. Stereozoom microscope, 7 to 30 power	1. Bausch & Lomb or equivalent
2. Two parallel penlight fluorescent tubes mounted on either side of the objective lens were used to provide flatfield illumina- nation. (No longer avail- able from AO Spencer)	2. Use either: (a) Bausch & Lomb Ring Illuminator with power supply (b) American Optical 384 Ring Illuminator with Power Supply
3. Drill vise	3. Or other suitable fixture
4. Bard & Parker No.5 knife handle with No. 15 blade	4. Or other suitable knife or scalpel
5. Stainless steel beaker, 600 ml.	5. Or other suitable stainless steel container
6. Adjustable temperature electric hot plate	6. Or other suitable electric heat source
7. Polaroid MP-4 Land Camera	7. Very useful where photographic documentation is employed. There are alternatives but be sure of ability to do the job

APPENDIX C

Apparatus Used in Feasibility Study of "High Vacuum Melt Test"

Apparatus	Comments
1. Analytical balance	1. Not used, but provision for weighing sample would be required in a formal test
2. Bell jar base, equipped with a mechanical vacuum pump and oil diffusion pump inlet, a roughing vacuum gage and a Vacuum Industries Inc. (subsidiary of GCA Corporation) electron tube vacuum gage, together with wiring for outside electrical power to be used inside the bell jar base. A suitable bell jar to fit the vacuum base	2. The vacuum equipment used at NAC was grossly oversized for the application. It was used because of ready availability. The bell jar was 28 inches in diameter and 30 inches tall and so heavy that a hoist was employed to lift it. Suitable equipment should have the ability to hold a vacuum of 1×10^{-6} mm of Hg (Torr) and suitable gaging to measure the pressure in the bell jar or vacuum chamber

APPENDIX D

Apparatus Used in "Mass Spectrometry Test"

Apparatus	Comments
1. Analytical balance (.1 mg. sensitivity)	1. Used to determine original sample weight, a value which is required in determining weights of outgassed products
2. Mass spectrometer equipped with a sample inlet chamber and a suitable recording device. The sample inlet chamber must be able to withstand pressures of at least 10^{-6} Torr and temperatures of 650°F. A suitable recording device would include a LBO (Light Beam Oscillograph) or a computerized data reduction system.	2. The sample is placed in the vacuum chamber inlet and evacuated to 10^{-6} Torr. The sample is then heated to 650°F for five minutes. At this time any outgassed products are sampled by venting the vacuum chamber to the mass spectrometer.

APPENDIX E

Apparatus Used in Feasibility Study of "Carbon Determination Test"

Apparatus	Comments
1. An analytical balance	1. Any analytical balance suitable for weighing to 0.1 milligram would be adequate
2. A Laboratory Equipment Corporation (LECO) Model 523 high frequency induction furnace was used for pyrolysis of the electrolytic tin plated alloy 42 lead material. The analysis of the pyrolysis products to determine the amount of carbon released as carbon dioxide was made with LECO Model 598-500 Direct Reading Carbon Analyzer	2. The procedures of ANSI/ASTM E350-77; Section 169-179 Combustion Thermal Conductivity or Section 103-113, Combustion Gravimetric should be exemplary

APPENDIX F

Derivation of the Last Line of Table VII
Mass Spectrometry Analysis of Table VI
Expressed as Volumes of Gas at Standard Temperature and Pressure

1. By trial and error, it was found that an 0.17 inch length of tin plated shorting bar weighed very close to 10 mg.
2. The length of shorting bar required to provide a 1g sample of tin plated Alloy 42 lead of cross section .04" x .01" is by ratio and proportion.

$$\frac{1g}{.01g} = \frac{X}{.17 \text{ inch}} \quad \text{or } X = 17 \text{ inches}$$

3. The surface of the tinplated lead is composed of four surfaces.

$$\text{The top found by 17 inches length X .04" = } 0.68 \text{ in}^2$$

$$\text{The bottom found by 17 inches length X .04" = } 0.68 \text{ in}^2$$

$$\text{One side found by 17 inches length X .01" = } .17 \text{ in}^2$$

$$\text{Other side found by 17 inches length X .01" = } .17 \text{ in}^2$$

$$\text{Total tin plated area} = 1.70 \text{ in}^2$$

4. Our thickness determinations show that the average tin plating thickness in this area is .001 inch.

5. The volume of tin from which outgassing (offgassing) was evolved

$$= .001 \text{ inch X } 1.70 \text{ in}^2 = .0017 \text{ in}^3$$

$$.0017 \text{ in}^3 = .120 \text{ inch } (.303 \text{ cm}).$$

6. Expressed as cm^3 , the total volume of tin plating is $(.303 \text{ cm})^3 = .028 \text{ cm}^3$

7. The increase in volume is found by $\frac{\text{total outgassing volume}}{\text{volume of tin outgassing}}$

8. Calculations for last line of Table VII:

Sample	AV	BZ	CV	DZ
Total volume of outgassing, cm^3 at STP	0.0232	.160	0.0343	0.0400
Cubic centimeters of tin plating that was outgassed	0.028	0.028	0.028	0.028
$\frac{\text{Volume of Outgassing}}{\text{Volume of Tin Plate}}$.8	5.7	1.2	1.4

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APPENDIX G

SAMPLE CODE

The final letter of the code identifies the type of lead finish.

V = Matte Acid Tin Plate (Wren Tin a Typical Bath)

Z = Bright Acid Tin Plate

Y = Furnace Reflowed Matte Tin Plate

W = Solder Dipped Matte Tin Plate

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11 SUPPLEMENTARY NOTES		12 SPONSORING MILITARY ACTIVITY
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13 ABSTRACT		
<p>The outgassing characteristics of matte deposits from generic bright acid tin baths which are operated to produce matte deposits are very similar to the outgassing characteristics of bright acid tin. Methods are proposed to differentiate between true matte tin and a matte tin finish produced by a generic bright acid tin bath.</p>		

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